THIN FILM MAGNETIC WRITE HEAD WITH PRECONDITIONING GAP

BACKGROUND AND SUMMARY

At present, most digital magnetic recording systems, such as those used for hard disk drives for personal computers, do not erase previously recorded data before recording new data. This is commonly known as recording in a direct overwrite mode. However, it has been found that writing in a direct overwrite mode increases the uncertainty of the exact location where a magnetic transition has been placed corresponding to the new data. This uncertainty reduces the system's signal-to-noise ratio (SNR) which has the practical limitation of reducing the system's effective storage capacity. As the bit lengths in digital recording become shorter from their already submicrometer dimensions, the ability of existing systems to write sharp transitions at particular locations lessens due to the previously written data encountered in the direct overwrite mode. As a result, signal degradation in the form of signal amplitude reduction, output pulse shape broadening, and pulse position shifts are experienced. This continuing progress in reducing the size of bit lengths and track dimensions require even more accurate recording of sharp transitions to achieve digital data density resulting in improved performance. Therefore, erasing previously recorded magnetic information would be desirable in any digital magnetic recording system, but practical implementation of this erase operation remains elusive for many applications. For example, consider the tracks in rigid disk systems. These tracks are narrow, nearing the micrometer width, are separated by distances smaller than even the track width's micrometer dimension, and these track dimensions are rapidly shrinking with each new product iteration seeking greater data density. In these applications, erasing previously recorded data before writing with conventional magnetic recording heads might be thought of in a couple of ways. One such way is for the read/write head to erase the portion (sector) of the track to be recorded on one pass of the head, and then the next pass of the head would be used to record new digital data on the previously erased sector. An obvious drawback with this approach is that it would require a time consuming extra revolution for all write steps. This delay, presently 16 milliseconds for a 3600 rpm disk drive, is larger than any other single delay for the system and would degrade overall data transfer performance. Another approach could include providing a separate erase head physically positioned "upstream" of the conventional write head, and displaced in position as with other prior art video or audio erase heads. In analog audio or video tape recording, an erase step is used to precondition the medium by erasing the old information with a separate erase head. In these systems, the erase head is physically distinct and separated from the recording head spatially and in design. The erase head may be displaced from the record head by several centimeters; may erase multiple tracks of old information in the same pass; may have a large magnetic gap for deep penetration of the magnetic field into the medium; and may use a single DC or AC applied current to erase the medium. However, there are problems in utilizing this approach with digital magnetic recording systems including the problem of physically aligning the two heads with respect to each other and with respect to the track to be overwritten. At present data densities and track dimensions, this is at least difficult and perhaps overwhelmingly challenging with track pitches projected to be 100 nanometers or less, especially considering that the heads must be consistently aligned over time, with temperature and other mechanical deviations providing further complications. Still another approach would include fabricating a second head to perform the erase function directly over the conventional write head. This approach could be considered in thin film heads which are widely used for digital magnetic recording systems. However, there would be significant cost and complexity added to the manufacturing process due to the additional steps involved with this approach.

To solve these and other problems in the prior art, the inventor has succeeded in developing a design for a thin film head with an integrated preconditioning gap which may be constructed with only a slight modification to the present manufacturing techniques utilized to construct thin film recording heads. It is anticipated that this modified construction may be achieved with only a small processing cost and without significantly reducing the expected yield of the delicate thin film manufacturing process. In essence, the inventors' design utilizes the same layering of a first magnetic pole piece, a pancake magnetic coil, and a second magnetic pole piece magnetically coupled to the first pole piece with one set of edges being spaced to form the magnetic gap therebetween. However, the bottom or first pole piece would have an extended length so as to underlie the entirety of the pancake coil, and a third pole piece is provided which magnetically couples to the extended tail of the bottom or first pole piece to thereby encircle the back half windings of the pancake coil. The second gap or preconditioning gap is thereby formed between this additional third pole piece and the second pole piece.

In sum, using conventional thin film manufacturing techniques and present designs, a thin film magnetic recording head may be conveniently manufactured with an intricately formed preconditioning gap to provide an on-the-fly erase function. This device has applicability to both perpendicular and longitudinal recording. Due to its being manufactured in an integral, single head, the preconditioning gap is always aligned with the write gap and suffers the same environmentally induced degradation such as through temperature, stress, or the like such that it remains so. Furthermore, there is no intervening spacing between the preconditioning gap and the write head as the center pole piece forms part of the magnetic circuit for each of these two gaps. Therefore, once manufactured, the preconditioning gap is aligned, its performance may be measured and tested to verify its operating parameters, and could be expected to remain in that condition over time and through its useful life. As the center pole piece is energized by a single coil, and the center pole piece forms part of the magnetic circuit for both gaps, there is no requirement for a second magnetic coil. This reduces cost, manufacturing complexity, eliminates alignment problems, and contributes to the invention's elegantly simple design. Furthermore, there is no need for a separate "erase" signal as the write signal which energizes the coil is used.

This same concept may also be implemented in a ring head coil construction with a center pole comprising an I-pole piece having a coil wrapped therearound and two C-pole pieces surrounding the I-pole piece.

While the principal advantages and features of the present invention have been explained, a fuller understanding of the invention may be gained by referring to the drawings and description of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of a conventional inductive write head as known in the art,

FIGS. 2(*a*) to (*d*) are perspectives detailing the construction of a thin film inductive head or write head manufactured through layering processes as known in the art,

FIGS. 3(*a*)–(*d*) are perspective views detailing the construction of the thin film inductive head of the present invention,

FIG. 4 is a schematic representation of the prior art construction of a ring head coil detailing the use of two C pole pieces,

FIG. 5 is a schematic representation of a prior art ring head coil utilizing a C and I pole piece, and

FIG. 6 is a schematic representation of a ring head coil arrangement illustrating a write head with preconditioning gap of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIG. 1, it is well known in the prior art that a conventional inductive write head **20** is formed with a head core **22** made of magnetic material and formed in the general shape of a C with a gap **24** wherein a gap fringing field **26** is formed through energization of a coil **28** energized from a current source **30**, all as is well known in the art. Also, a side fringing field **32** is formed along the side edges of gap **24**. The magnetic flux in the gap fringing field **26** is emitted during writing, or erasing, as coil **28** is energized to magnetize a magnetic medium (not shown) which passes across the face **34** of head core **22** and adjacent gap **24**. The conventional head structure depicted in FIG. **1** has been dramatically improved on and miniaturized over the years since its discovery to present day techniques which include a new method of fabrication known as thin film.

Thin film head construction is depicted in FIGS. 2(*a*)–(*d*). In this method of construction, a substrate **36** forms a base over which a first pole piece P_1 (**38**) comprised of a thin film of magnetic material is laid. Over pole piece P_1, a thin pancake coil **40** is laid wound in a spiral with its leads **42**, **44** for electrical connection to an appropriate current source (not shown). As shown in FIG. 2(*c*), a second pole piece P_2 (**46**) overlies one side of the windings comprising coil **40** with a connector **48** attaching pole piece P_2 to pole piece P_1 in an appropriate mechanical orientation to form gap **50** therebetween at the tips **52**, **54** of pole pieces P_1, P_2, respectively. A lead connector **56** is also applied to provide a convenient means for connecting the interior coil lead **44** to an external current source (not shown). As shown in FIG. 2(*d*), the windings of coil **40** surround pole piece P_2 to induce a magnetic flux in the gap **50** formed between pole tips **52**, **54**.

The present invention builds on the prior art construction of thin film magnetic heads and is depicted in FIGS. 3(*a*)–(*d*). As shown in FIG. 3(*a*), a pole piece P_1 (**100**) is provided which extends for a greater distance along substrate **36** so as to underlie coil **102** and extend beyond the outer edges of its back winding. This is depicted in FIG. 3(*b*) with coil **102** covering substantially the entirety of pole piece P_1 (**100**). As shown in FIGS. 3(*c*) and (*d*), pole piece P_2 (**104**), similar to the prior art construction shown in FIG. 2, overlies the front of coil **102** and is connected to pole piece P_1 (**100**) at the center of the coil **102**. However, a third pole piece, P_3 (**106**) overlies pole piece P_2 (**104**) and the back half of coil **102** where it is magnetically coupled to pole piece P_1 at its rear most end **108**. As perhaps is best shown in FIG. 3(*d*), coil **102** thereby surrounds pole piece P_2 (**104**), similar to the prior art construction shown in FIG. 2, however, a second magnetic circuit is formed between pole piece P_2 (**104**), the back half of pole piece P_1 (**100**) which is joined at junction **108** to pole piece P_3 (**106**) to thereby form a preconditioning gap **110** between the tip **112** of pole piece P_2 (**104**) and the tip **114** of pole piece P_3 (**106**). This second, preconditioning gap **110**, is in addition to the write gap **116** formed between the tip **112** of pole piece P_2 (**104**) and the tip **118** of pole piece P_1 (**100**).

In the present invention, the preconditioning gap **110** serves to precondition or magnetize into a known state, the magnetic medium prior to its presentation to the write gap **116**. As this magnetization is induced by the preconditioning gap **110** is well known, and is directly related to the write field as it is being driven by the same write current, much more precise placement of the transition onto the medium may be achieved. This will provide a significant improvement in the SNR and accommodate an increase in the system capacity by increasing data density. Although the dimensions for write gap **116** and preconditioning gap **110** may be selected as desired to accommodate any particular application, the inventor contemplates that a write gap of between about 0.15 and about 0.25 microns is presently considered typical, and these dimensions are decreasing as development continues such that a write gap of 0.10 microns is expected soon. Similarly, the preconditioning gap **110** width may be chosen as desired but the inventor contemplates that a width of approximately 0.5 microns or less will provide the preconditioning effect as desired for preconditioning the magnetic medium. Similarly, the pole tip width of each pole piece may be chosen to provide appropriately sized erase and write tracks, depending upon the particular application. One such configuration might include a preselected pole tip width for P_1, a wider pole tip width for P_2, and a pole tip width of P_3 the same as that of P_1. This arrangement would provide a larger erase track width to overcome the potential problem of not completely erasing old information due to improper head alignment. Although, it would not be uncommon for the pole tip widths to be equal to provide erase and write track widths of comparable width. As is known in the art, the pole tips may be sized by planar lithography, pole tip trimming, or some other equivalent method.

In operation, a magnetic medium (not shown) would traverse the head construction of the present invention as depicted in FIG. 3(*d*) from right to left such that it would first be subjected to the magnetic field induced by preconditioning gap **110** to precondition it. As that portion of the magnetic medium passes under write gap **116**, its induced magnetization is known as it has been preconditioned or magnetically "written to" by preconditioning gap **110**. Although, as mentioned above, the gap size for preconditioning gap **110** may be chosen as desired, it is presently thought that A-C erasure is more desired. Hence, a wider preconditioning gap **110** with a higher frequency data write signal will provide a decaying alternating field that will set the state of magnetization on the magnetic medium closer to that expected to be achieved with true A-C erasure. This is due in part to a wider gap not being as effective in creating a sharp transition. However, this is just one example of a particular construction which may be utilized, depending upon the particular application chosen.

There may also be manufacturing considerations which would impact on the choice of individual pole piece construction or gap sizing. For example, as depicted in FIG. 3(*d*) and explained herein, pole piece P_1 (**100**) has been chosen to extend under the full width of coil **102**, with pole piece P_2 (**104**) attached near its center or medial portion, and pole piece P_3 (**106**) attached near its end opposite the tip end. However, other alternative construction could be used and still satisfy the magnetic requirements of the head of the present invention. For example, pole piece P_2 may be chosen